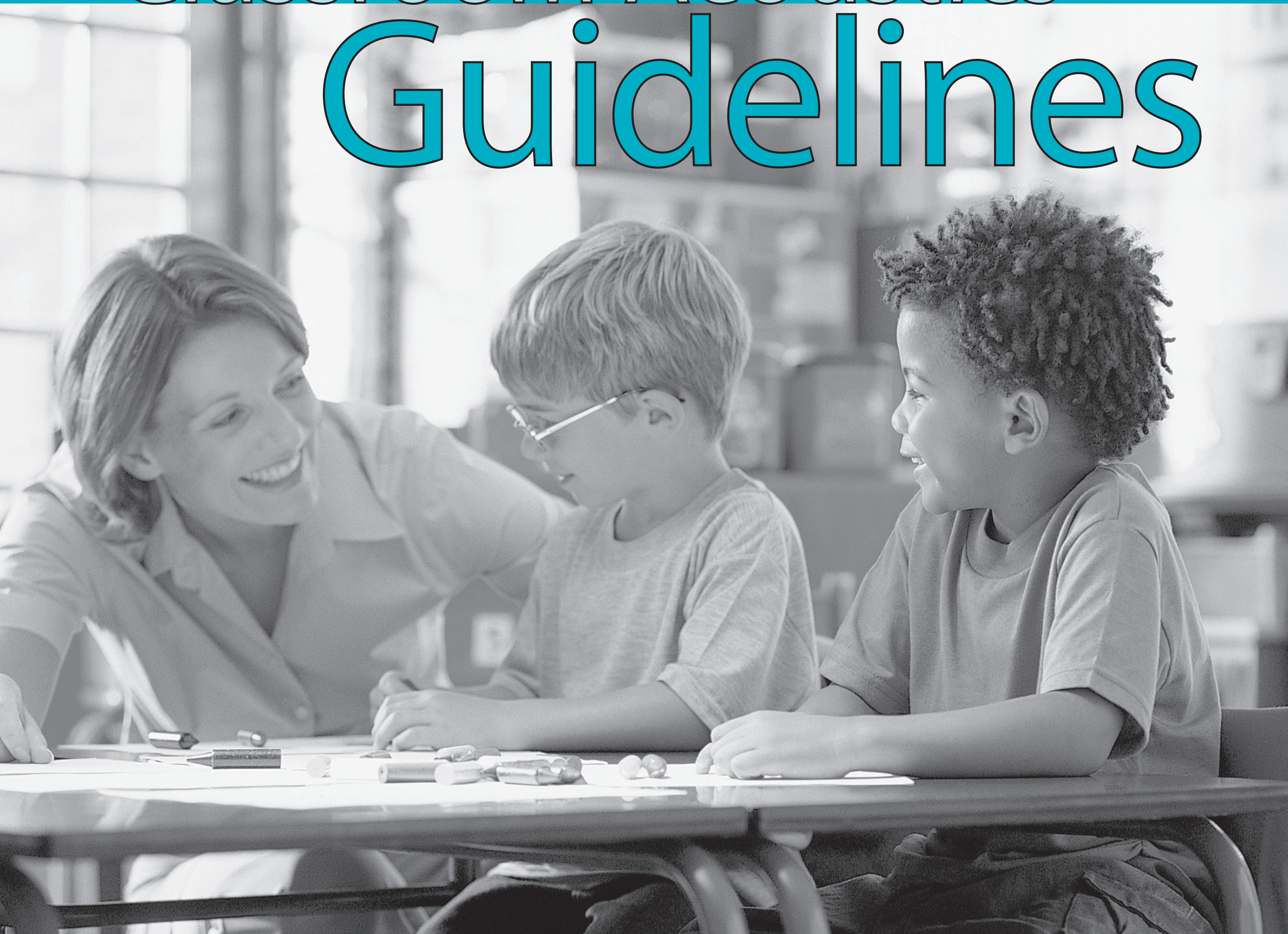
Classroom Acoustics Guidelines



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Classroom Acoustics Guidelines

Maryland State Department of Education

FOREWORD

The Maryland State Department of Education (MSDE) has the opportunity to make a positive change in the learning environment of all children in Maryland by supporting efforts to enhance the listening environment in schools. The American National Standards Institute (ANSI) recently adopted *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools (ANSI S12.60-2002)* as a voluntary standard for new construction and renovation projects. MSDE supports the implementation of this standard in capital improvement projects in all public school buildings.

The learning environment in the classroom in particular has been long compromised by poor acoustics. According to the Acoustical Society of America, in many classrooms in the United States, the speech intelligibility rating is 75% or less. This means children miss at least every fourth word from the teacher - words that carry information the student is expected to learn and apply. If adults miss every fourth word, they are able to do a reasonable job of filling in the gaps; however, children do not have the language skills and knowledge to fill in the gaps while also learning content material. Poor listening environments should be unacceptable for children.

The purpose of the MSDE guidelines on classroom acoustics is to raise awareness of the importance of acoustics in schools and to provide guidance regarding the ANSI standard to design teams for major capital projects. These guidelines also will provide technical assistance to public school staff for meeting the Individual Educational Plans of students with disabilities and for responding to individual complaints and unique acoustic situations.

Benefits to implementing the new acoustics standard include improved student behavior, reduced vocal strain on teachers, and increased academic achievement, especially in the primary grades. The most numerous beneficiaries will be children for whom English is a second language. In addition, the new standard may reduce special education costs by reducing the number of children with hearing loss who require special services outside of the general classroom. With the mandate for inclusion nationwide, all children with special needs should be a part of the regular classroom. Good acoustics in schools are critical for the success of our diverse student body.

Nancy S. Grasmick
State Superintendent of Schools

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IMPORTANCE OF GOOD ACOUSTICS IN CLASSROOMS

Sixty percent of classroom learning activities involve listening to and participating in spoken communication (ANSI, 2002). It is essential that speech be effectively communicated teacher to student and student to student. Teachers who must shout to be heard are not effective communicators. Students who must struggle to listen are not effective learners. “Children are not only smaller and noisier than adults, they are immature and inefficient listeners who are developing their speech perception abilities until their teen years” (Nelson, 2003). Empirical studies highlight the adverse effects of poor classroom acoustics on academic achievement. The Educational Audiology Association summarized the results of improvements in classroom acoustics: higher achievement levels for typically developing students and students for whom English is a second language, fewer students requiring tutorial services and special education, a reduction in the number of students who repeat a grade, and a reduction in teacher sick days.

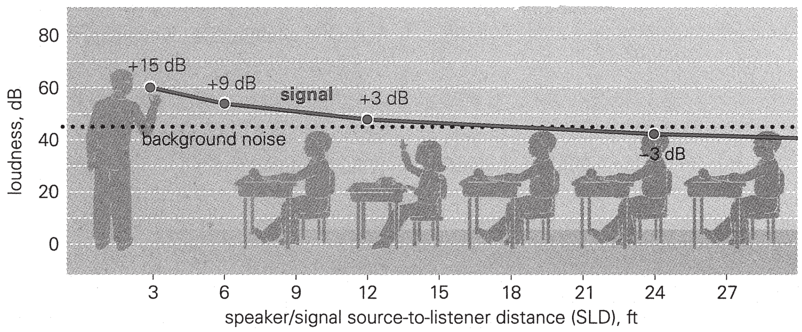
In quiet classrooms, teachers are able to speak using a comfortable vocal effort. In poor acoustical environments, teachers are required to increase their level of vocal effort, often resulting in stress and fatigue to their voices. U.S. teachers miss about two days per year on average due to this vocal fatigue (Lubman & Sutherland, 2001).

The typical U.S. classroom today has a diverse student population that may include students with learning disabilities, hearing loss (temporary or permanent), attention deficit disorders, behavioral disorders, who are learning English as a second language, and who are not native speakers of the language of instruction. In the aggregate this represents a large number of students. According to the U.S. Census Bureau report (1998), 20% of school-aged children speak a language other than English in the home and 5-11% of students have limited English proficiency. In the U.S., 4 out of 1000 infants are identified at birth with hearing loss (www.childrens.com/health care professionals.) The prevalence of hearing loss increases significantly by school age. Permanent hearing loss in young school age children increases to approximately 13 of 1,000 (ASHA 1995). Additionally, 13-15% have unilateral (one side) or mild hearing loss (Niskar, et al. 1998; Bess, et al. 1998).

The most important consideration for improving classroom acoustics is the signal-to-noise ratio (SNR) at the child’s ear (Ross, 1978). The SNR is defined as the sound intensity level produced by the teacher (the signal) in relation to the sound intensity level of the background noise. For example, if the speech is 65 decibels (dB) (average speech level standing 3 feet from the talker) and the background noise is 70 dB (the level of an overhead projector at about 2 feet), the SNR would be -5 dB. The projector’s noise obscures the speaker. A typical, excessively noisy classroom will vary in SNR from +5 to -7 dB.

In 1995, the American Speech-Language-Hearing Association (ASHA) recommended a SNR for all educational settings for all children of +15 dB. Bess (1998) showed at that time only self-contained classrooms for students with hearing loss met ASHA’s recommendation of +15 dB SNR. Extensive research into classroom acoustics has shown high levels of background noise are detrimental to the learning experiences of children in the classroom. Soli and Sullivan (1997) found that typical children younger than

Signal-to-noise ratio (SNR)



(Courtesy of Trane, a business of American Standard Companies)

13 years of age need the teacher's voice to be significantly higher than background noise in order to hear, whereas typical adults are able to hear with an SNR of approximately zero (equal volume for signal and background noise). Further research has revealed that young children have immature listening systems that must develop before they are able to function adequately in poorer listening environments.

While poor acoustics in the classroom negatively affect all children, adverse sound environments can be particularly detrimental to children with hearing loss, those learning in English as a second language, or those with an attention deficit or auditory processing disorder (Nelson). Young children with colds and ear infections often suffer temporary hearing loss. For students with hearing impairment to succeed in the classroom, they need an SNR 15 dB or better than their normally hearing peers (Ross, et al., 1991)

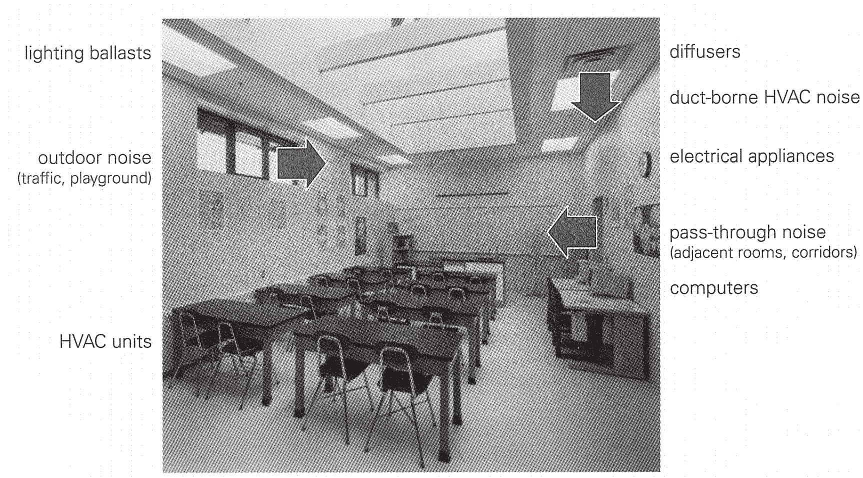
These findings, along with other perceptual factors and considerations, provided objective support for the development of national standards for classroom acoustics. The American National Standards Institute (ANSI) Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, S12.60-2002 (the Standard) specifies a background noise level of 35 dB, which would provide an SNR of approximately 15 dB assuming a comfortable speech level of 50 dB and no noise generated within the classroom by its occupants or their activity.

The SNR is controlled by two factors, the signal level of the teacher's voice at the student's ear and the background noise. The signal level of the teacher's voice is controlled, in turn by the teacher's voice effort (e.g. - usually between normal and raised) and the decrease in this voice level with distance between the teacher and the student. With every doubling of distance between the speaker and the listener in the direct sound field, there is a clearly noticeable loss of 6 dB in signal level. Both the teacher's voice level and the distance between teacher and student depend on the teacher and how she or he controls the seating arrangement. Except for noise from any teacher-controlled instructional equipment, such as projectors, the background noise is totally dependent on facility designer-controlled factors. These consist of the noise from the internal building equipment, such as heating, ventilating, and air conditioning (HVAC), plumbing,the amount of noise isolation between the classroom and adjacent spaces or the noise isolation between the outdoors and the classroom interior.

The impact of noise on children with normal-hearing sensitivity and mild or unilateral hearing loss should not be underestimated. Bess, Tharpe, and Gibler (1986) reported a significant difference in listening abilities of students with unilateral hearing loss compared with normal-hearing students when speech was presented in a background of noise. Crandell (1993) reported the results of a study in which words were presented in a background of noise, 6 dB SNR, often found in a typical classroom. Children with normal hearing sensitivity missed 25% of the words and children with minimal hearing loss missed 50% of the words.

The second factor contributing to speech intelligibility is reverberation time (RT), measured in tenths of seconds, which may be thought of simply as the "echo time within the classroom." It is well known that as RT increases, speech intelligibility decreases especially for young children. In a room with a lot of hard, reflective surfaces, it takes a long time for the sound to fade away. (The room has a lot of echo.) This type of room; e.g., a gymnasium, would have a large or long RT. The echo is created by reflected sound waves bouncing around the room. In a room with a lot of absorbent surfaces, the sound energy is dissipated quickly (e.g., less echo) and the RT is low or short. The Standard states that RT must not exceed 0.6 seconds for small classrooms. Typical classrooms have a greater value. Children with special needs require an even smaller RT for optimal listening in the classroom (Ross, 2001). In fact, ASHA recommends RT of 0.4 seconds for children with hearing loss (1995). A high SNR combined with low RT is optimal for student listening and learning.

Sources of background noise in an unoccupied classroom



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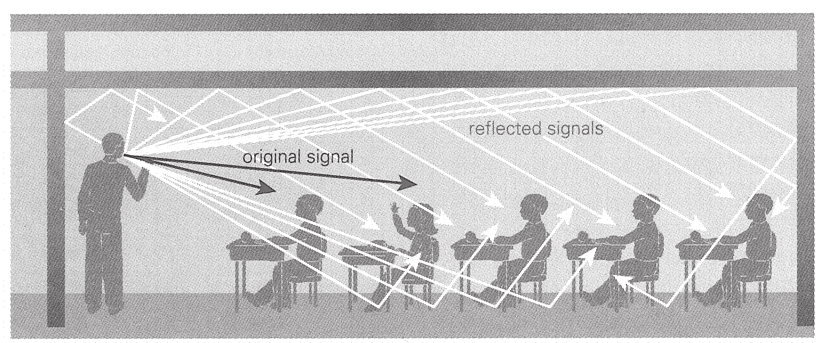
Reverberation



(Courtesy of Trane, a business of American Standard Companies)

In summary, the factors controlled by the design of the classroom that influence childrens' ability to hear speech accurately and thus learn in the classroom are the background noise in the unoccupied classroom and its reverberation time.

DEVELOPMENT OF THE STANDARD

It has long been known that noise in the classroom adversely affects the learning environment. On the forefront of this acknowledgement have been several European countries, including France, Germany, Portugal, Sweden, Italy, and the United Kingdom (UK), that have adopted acoustic standards into their school design and construction guidelines. Following the recommendations made by some of its concerned members the Acoustical Society of America (ASA) initiated development of the first national standard for classroom acoustics in 1997. In 1998, the U.S. Access Board, the federal agency that is responsible for developing the guidelines to remove architectural barriers under the Americans with Disabilities Act (ADA), formally initiated research to address the need for acoustical accessibility standards for schools. They started this by publication in the Federal Register of a Petition for Rule Making and a Request for Information (RFI) on (Classroom) Acoustics. This action was triggered by a petition to the Board from the parent of a child with a hearing loss and at the persistence of several consumer and professional organizations. In 1999, the Access Board voted to support the ongoing efforts of the ASA to develop standards that would later be adopted by the American National Standards Institute (ANSI). The Standard was adopted in 2002, providing acoustical performance criteria and design requirements for classrooms and other learning spaces.

The general guidelines of the Standard are based on two primary acoustic performance factors: background noise and reverberation time. In an unoccupied core learning space of typical size, the one-hour average A-weighted background noise should not exceed 35 dBA and RT should not exceed 0.6 seconds. While these standards are still voluntary, many school districts and several states now reference the standards in their new building guidelines, requiring architects and engineers to account for the acoustic effects of the HVAC systems, building construction, and materials selection for the instructional environment. In 2002, the Access Board submitted certain provisions of the Standard to the International Code Council (ICC) for inclusion in the 2003 International Building Code (IBC). At the September 2002 ICC meeting the proposal was not adopted due to concerns about associated costs and compliance issues. Supporters have shown strong interest in continuing to pursue inclusion of the standards in the IBC. In the meantime, the Standard has set a stringent voluntary design goal for schools and classrooms.

ACOUSTICS 101 FOR CLASSROOMS

Acoustic design relies on basic physics. The definition and descriptions used in this section rely on the textbook *Architectural Acoustics* by M. David Egan.

Sound radiates in all directions from its source in waves. The waves continue until they reach a surface that absorbs or reflects them. There is always a sound source, a path, and a receiver. Examples of sound sources in a classroom, the teacher, furniture being moved, children, and equipment such as motors and fans. The air in the classroom and the solid materials associated with the ventilation ducts, building structure, ceiling, flooring, and walls are the "path" the sound wave travels through. The students are the "receivers."

Sound travels at a velocity of about 1,120 feet per second. Sound waves, like ripples on the surface of a lake, have a frequency measured in cycles per second [or Hertz (Hz)] and wavelength equal to the sound velocity divided by the frequency. Normal speech has a frequency range from 125 to 8,000 Hz and a corresponding wavelength range from nine feet down to 1.7 inches. People with normal hearing are capable of hearing sounds with frequencies between 20 and 20,000 Hz. The frequency is perceived as pitch. The tuning pitch "A" is 440 Hz. "C below middle C" has a frequency of 131 Hz and a wavelength over eight feet. Most sounds are complex waves with a variety of high and low sound pressures containing energy over a wide range of frequencies.

Sound level is measured in decibels. Changes in sound pressure are perceived by the ear as changes in loudness. The human hearing range for sound level is from 0 dB the approximate "threshold of hearing" to 130 dB at "the threshold of pain." A whisper is 20 dB, normal speech between 50 and 70 dB, noise in a hard-surfaced cafeteria is 80 dB, an amplified rock band is 120 dB, and a jet engine at 200 ft away is 130 dB. A change in sound level of 1 dB is barely perceptible. A change of 5 dB is clearly noticeable. An increase in sound level of 10 dB is perceived as approximately twice as loud as the original sound.

Sound levels fall off dramatically as distance from the source increases (e.g. by 6 dB outdoors for every doubling of distance from a source). A teacher's normal speaking voice may be 65 dB for a student three feet away in the front row, but 55 dB (one-half as loud) for a student 30 feet away in the back of the room, depending on room shape and surface materials.

Sound absorption for a room can be expressed in terms of its sound absorbing efficiency. This is equal to the product of the surface area of the sound absorption material and its sound absorption coefficient. Materials with high sound absorption coefficients (usually > 0.70) are called "sound-absorbing." Those with low coefficients (< 0.10) are "sound-reflecting." The Noise Reduction Coefficient (NRC) is a single number average of sound absorption coefficients of a material at certain frequencies in the speech range and is used by architects and engineers in specifying materials for acoustical absorption treatment. NRC values are useful to assess sound absorption for everyday situations, but because the higher and lower frequencies are excluded from the calculation, they should not be used to evaluate materials in spaces that require a very high degree of musical or speech perception, such as music practice/rehearsal rooms or auditoriums and classrooms. They also cannot be used directly, without supporting manufacturer's test data and description of how the tested sample was supported, to satisfy conformance to the reverberation time limits in the Standard at the three frequencies of 500, 1,000, and 2,000 Hz.

Reverberation time (RT) is the time required for sound to decay 60 dB after the source has stopped. It increases in direct proportion to the volume of the room and decreases inversely as the amount of sound absorption in the room increases. The RT required by the Standard for typical classrooms is much lower than for large lecture halls or school auditoriums. The range of satisfactory RTs for the later will vary with the type of source and the hearing acuity of the listener. For such rooms, the optimum RT for speech is from 0.4 to 1.2 seconds, between 1.0 and 2.5 seconds for music, and for speech and music between 0.8 and 1.8 seconds. To hear clearly in large rooms, hearing-impaired, elderly, and very young listeners require lower reverberation times by as much as 0.5 seconds.

Surrounding a high level noise source, such as a mechanical equipment or band practice room, with solid, massive, and noise leak-resistant enclosures can isolate sounds. (Think of the heavy, well sealed wall surrounding a recording studio.) There is a numerical measure of the capability of a structure to provide sound isolation. The Sound Transmission Class (STC) is the single number rating of the effective mid-frequency sound isolation performance of a wall or roof-ceiling assembly tested in the laboratory. For example, a single pane of 1/8-inch glass has an STC rating of 26. A painted, eight-inch, lightweight concrete block wall has an STC rating of 49. The actual reduction in decibels provided by a wall or roof/ceiling assembly with a given STC rating also will depend on the type of noise source. For example, the reduction in typical highway noise will be 15 to 20 dB below the STC rating of the external wall used to reduce such noise inside the classroom, and about 17 to 22 dB below the exterior wall STC rating for aircraft noise. The composite STC rating of a complete wall assembly accounts for the STC ratings of each component according to their relative areas such as window and solid wall components.

In addition to airborne sound transmission through walls, ceilings, and floors, impact noises can be transmitted by vibration through a structure. The Impact Isolation Class (IIC) rating is a single number measure of the reduction in impact sound structurally transmitted through a floor-ceiling assembly. A bare concrete floor may have an IIC rating of 25. A wooden floor "floated" above the structure with isolation pads and hangers may have an IIC rating of 57.

Mechanical system noise and vibrations are usually the primary source of background noise in classrooms. Mechanical equipment produces vibrations that can become structure-borne sounds and airflow turbulence that becomes airborne fan noise, air outlet noise, and duct system noise. Noise levels from stand-alone equipment including wall- or window-mounted air conditioning units are especially high for current off-the-shelf systems. It is prudent to measure noise of stand-alone equipment in similar conditions before specifying such equipment.

Sound travels between the source and receiver through many sound and vibration transmission paths. Different sources produce sounds at different frequencies that can result in throb, rumble, roar, whistle, whir, and hiss sounds. Different noise reduction methods may be required to isolate these sounds based on specific sound pressures, frequencies, and transmission paths. It is prudent to plan noise controls early in the design process.

TABLE 1

Maximum A-weighted one-hour average steady background noise levels and maximum reverberation times at 500, 1,000, and 2,000 Hz in unoccupied learning spaces (ANSI S12.60, 2002)

Space	Max. Background Noise[(a)]	Max. Reverb time
Typical Classroom Core Learning Spaces less than 10,000 cu.ft. (<1,000 sq.ft. room w/10 ft. ceiling)	**35 dB**	**0.6 seconds**
Kindergartens, Science Labs, Other Large Classrooms Core Learning Spaces greater than 10,000 cu.ft. and less than 20,000 cu.ft. (1,000 - 2,000 sq.ft. room w/10 ft. ceiling)	**35 dB**	**0.7 seconds**
Media Centers, Technology Education Labs, Cafeterias, Gymnasia, Etc. Core Learning Spaces greater than 20,000 cu.ft. and all Ancillary Learning Spaces (> 2,000 sq.ft. room w/10 ft. ceiling)	**40 dB**[(b)]	[(c)]

(a) *The limit for C-weighted levels is 20 dB higher.*

(b) *The limit for corridors not used for formal instruction is 45 dB.*

(c) *See Annex C of ANSI S12.60, 2002 for guidance for controlling reverberation in such spaces.*

KEY PROVISIONS OF THE STANDARD

The Standard provides acoustical performance criteria, design requirements, and design guidelines for new school classrooms and other learning spaces. It may be applied when practicable to the major renovation of existing classrooms. The Standard uses typical design and construction practices familiar to architects and engineers and does not require school systems to hire acoustic consultants. The Standard does not rely on sound field amplification systems.

The ANSI issues consensus standards for voluntary compliance on many architectural and engineering subjects. Many of these standards are formally adopted and referenced in building codes and then enforced by local codes officials. This Standard was developed for ANSI by the Acoustical Society of America (ASA) in partnership with the U.S. Access Board. It requires reaffirmation, revision, or withdrawal action by the ANSI every five years. It was initially approved June 26, 2002.

The Standard defines two types of learning spaces - core learning spaces and ancillary learning spaces. The primary functions in core learning spaces are teaching and learning. These spaces include, but are not limited to, enclosed or open plan classrooms, instructional pods or activity areas, group instruction rooms, conference rooms, libraries, offices, special education resource rooms, offices used for educational purposes, and music rooms for instruction, practice, and performance. The Standard does not recommend using partially enclosed or open plan classrooms because of their inherently low noise isolation between adjacent learning spaces.

The primary educational functions for ancillary spaces are informal learning, social interaction, or activities other than formal instruction. These spaces include, but are not limited to, corridors, cafeterias, gymnasia, and indoor swimming pools. Although formal instruction does sometimes occur in these spaces, it typically is less rigidly based on verbal communication.

The performance criteria in the Standard do not apply to special-purpose classrooms such as teleconferencing rooms or other spaces such as large auditoria.

The acoustical performance criteria are specified by limits on maximum, one-hour, A-weighted and C-weighted background noise levels and limits on maximum reverberation times as shown in Table 1. The A-weighted noise level (dBA) is conventionally used to measure room noise because it deemphasizes low frequency sound, as do human ears. It simulates the sensitivity of the average human ear to typical environmental sounds. C-weighting (dBC) simulates how the ear perceives very loud sound and retains the measurement of low frequency sounds.

TABLE 2

Minimum STC Rating Required Between Core Learning and Adjacent Spaces (ANSI S12.60, 2002) [a,b]

Adjacent Space	Minimum STC
Other enclosed or open core learning spaces, speech clinic, health care room, and outdoors	50
Common use and public use toilet room and bathing room	53
Corridor, staircase, office, or conference room	45
Office and conference rooms where acoustical privacy is critical	50
Music room, mechanical room, cafeteria, gymnasium, and indoor pool	60
Mechanical room with fans circulating less than 140 cu.m/min (5000 cfm)	45

[a] *The STC rating requirements of Table 2 shall also be employed for the design of temporary partitions that subdivide a learning space.*

[b] *See also four footnotes in Table 2 of ANSI S12.60, 2002 for further guidance on application of STC Ratings.*

Sounds such as rumble, hum, buzz, whine, hiss, or whistle from HVAC and other building services and utilities can interfere with speech communication. They can also be distracting or annoying to occupants of a learning space. These sounds must be controlled to eliminate disturbances.
The minimum sound transmission class (STC) ratings for single or composite wall, floor/ceiling, and roof/ceiling assemblies that separate enclosed core learning spaces from adjacent spaces are shown in Table 2 and Table 3.

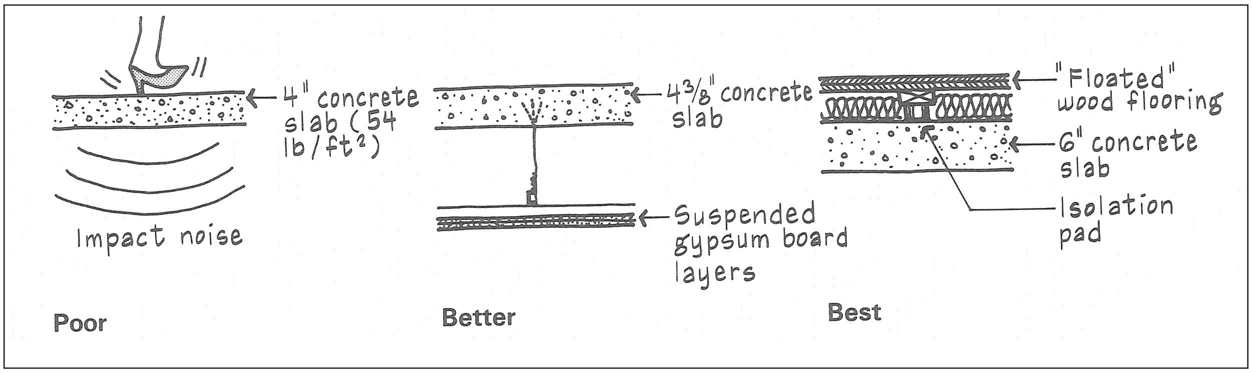
TABLE 3

Recommended STC Ratings Separating Spaces (ANSI S12.60 - 2002) [a]

	Corridor, Staircase, Toilet/Bathing Rooms	Music Room	Office or Conference Room	Outdoors	Mechanical Equipment Room, Cafeteria, Gym, or Pool
Corridor	45	60	45	45	55
Music Room	60	60	60	45	60
Office or Conference Room	45	60	45	45	60

[a] *See also six footnotes to Table 3 in ANSI S12.60 - 2002 for further guidance on application of STC ratings.*

Floor-Ceiling Assemblies



(Courtesy of M. David Egan)

Impact Insulation Class (IIC) rating of floor-ceiling assemblies of normally occupied rooms located above core learning spaces shall be at least 45 and preferably 50 without the benefit of carpeting in the room above. The IIC rating above ancillary learning spaces shall be at least 45. A concrete floor/ceiling slab with an IIC of 25 is poor at blocking impact noise. A "floating" floor installed on isolation pads above the concrete slab with an acoustical ceiling suspended on isolation hangers below at an IIC of 57 would much better isolate noise from impact.

In new construction, gymnasia, dance studios, or other spaces with high impact floor activities shall not be located above classrooms or core learning spaces. For refurbishment of existing facilities, if it is not possible to avoid such an incompatible condition, the IIC rating of floor-ceiling assembly shall be at least 70 when above core learning spaces not greater than 20,000 cu. ft. 65 when above core learning spaces greater than 20,000 cu. ft. and 65 when above ancillary learning spaces.

ANSI recommends conformance be verified by test but does not require testing. Annex E of the Standard describes appropriate measuring procedures and equipment. The following tolerances are allowed:

Background noise	Do not exceed limits by more than 2 dB
Reverberation time	Do not exceed limits by more than 0.1 second
Sound Isolation STC	Not less than 5 points below the specified rating
Impact Isolation IIC	Not less than 5 points below the specified rating

TABLE 4

Typical STC ratings of various wall constructions and related components

Typical Partition Construction	Typical STC Rating
6″ Concrete Masonry Unit (CMU) dense*	43
6″ CMU, painted	46
8″ CMU, lightweight*	46
8″ CMU, dense*	48
8″ CMU, painted	49
10″ CMU, painted	50
12″ CMU, lightweight*	51
12″ CMU, painted	51
12″ CMU, dense*	53
8″ acoustic CMU	53
6″ Normal Weight CMU, furring channels, 5/8 " gypsum wall board both sides	54
4 " metal studs, 5/8″ gyp. bd. each side, screw attach., joints taped and sealed (typ)	39
4 " metal studs, sound attenuation blankets, 5/8″ gyp. bd. both sides from slab to deck	43
4 " metal studs, 5/8″ gyp. bd. both sides from slab to deck	40
4 " metal studs, 5/8″ gyp. bd. both sides from slab to deck, resilient channel attachment	48
4 " metal studs, 5/8″ gyp. bd. both sides from slab to deck, screw att. to staggered studs	48
4 " metal studs, double layer 5/8″ gyp. bd. on each side	44
4 " metal studs, sound attenuation blankets, double layer 5/8″ gyp. bd. on each side	55
*Addition for sand filled cores	+3
*Addition for rigid furring attachment of gyp. bd. one side	+7
*Addition for rigid furring attachment of gyp. bd. both sides	+10
*Addition for resilient furring attachment of gyp. bd. one side	+12
*Addition for resilient furring attachment of gyp. bd. both sides	+15
*Addition for dividing wall into separate wythes with 4″ air space between	+15

Typical Classroom/Corridor Doors	Typical STC Rating
1-3/8″ Solid Core Wood Door with vision lite	22-26

Typical Classroom Windows	Typical STC Rating
Single pane double hung	22-26
Double-glazed aluminum casement window	30
Double-glazed wood casement window	29

Typical Exterior Walls	
4″ brick veneer with 2″ air space over 8″ CMU	50
4″brick veneer with 2″ air space over 1/2″ sheathing, 4″ metal studs, 1/2″ GWB	45
12″ CMU dense	53
8″ brick, solid	49
12 " brick, solid	54

EXISTING CONDITIONS IN TYPICAL CLASSROOMS

Poor acoustics is a problem in many schools. In a 2002 MSDE School Facilities Branch survey of fifty-two classrooms, respondents in seven out of seventeen different schools rated the classrooms as having poor acoustics or poor sound separation. Most facilities planners and architects are just beginning to perceive and acknowledge the existing problems.

The background noise level in the Standard for an unoccupied classroom of 35 - 40 dB is about the same level as an unoccupied living room. Researchers have measured background noise levels in typical classrooms. Twelve recent studies reviewed by the authors show measured background noise levels in unoccupied classroom levels from a low of 28 dB to a high of 78 dB. It is safe to say that most classrooms today have higher than recommended background noise levels.

The reverberation time recommended by the Standard for classrooms is 0.6 - 0.7 seconds. The reverberation time recommended by ASHA is 0.4 seconds (ASHA, 1995). A reverberation time of 0.4 - 0.5 seconds is about the same as that of an average living room with upholstered furniture and carpet. Four recent studies showed a range from 0.2 - 1.3 seconds in typical classrooms. Many classrooms have longer than recommended reverberation times.

Table 4 lists types of construction and materials commonly used in public school construction. The standard specifies an STC rating of 50 between adjacent classrooms. Both masonry and sound-insulated stud partitions can be designed to meet this rating. Masonry partitions are much more durable than gypsum board partitions in most school applications. The STC ratings are taken from current construction references and manufacturers and product association reports.

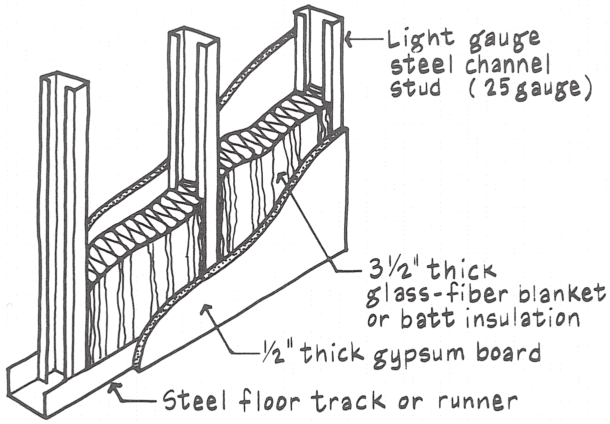
COST IMPACT OF THE STANDARD

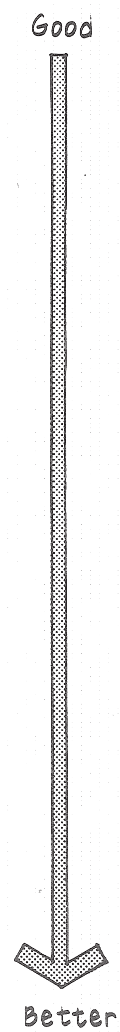
A life-cycle cost approach may be useful in looking at the cost impact of implementing the Standard in new construction. Initial capital construction costs are a small percentage of the thirty-year costs to staff, operate, maintain, and provide services in the school. A “pay as you go” approach, providing individual remedies for individual students with hearing loss on a case by case basis, will be expensive over time. Some students will require outside placement, some will require major alterations to existing classrooms, some will require out-of-class/in-school support services. There is also a societal cost to students who are delayed in acquiring learning and reading skills that may result in failure and loss of potential and to teachers who suffer vocal strain and increasing burnout.

Designing to higher acoustic standards is expected to increase the cost of new construction. The degree to which the cost increases depends on the starting point for construction within the school system. The

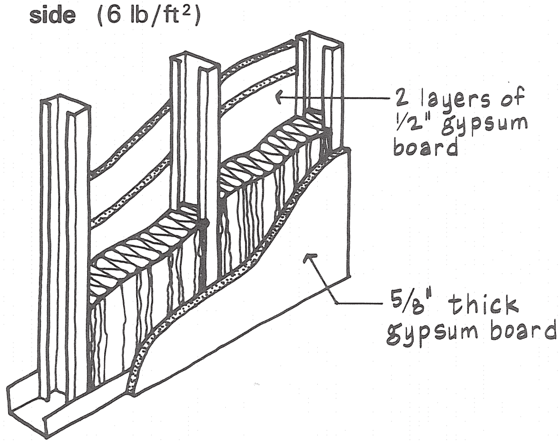
Metal-Channel-Stud Partition	Sound-Isolating Effectiveness

One layer gypsum board each side (4 lb/ft²)

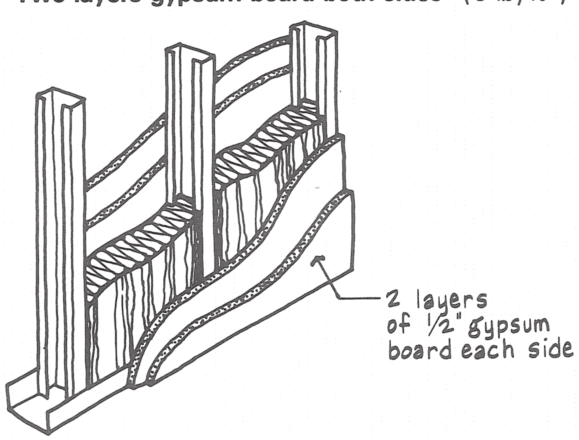




Two layers gypsum board one side, one layer other side (6 lb/ft²)



Two layers gypsum board both sides (8 lb/ft²)



(Courtesy of M. David Egan)

impact will be less for those systems already designing schools to stringent indoor air quality and energy conservation guidelines. These designs may already include central HVAC systems, a building enclosure, slab-to-slab partitions, and fire-rated doors in their design standards. The U.S. Access Board has been monitoring the costs. In 2003 they estimated that school systems currently in the top quartile for construction spending would incur an average 0.5% increase to meet the Standard with an average cost of 3% for schools at the spending median. Low-quartile systems still using through-the-wall fan coil units might see as much as 5 - 7% increases. The architect of several new schools in Connecticut designed to the Standard estimates the additional cost at approximately 1.5% of overall construction costs. Research for the similar UK standard suggested an average increase of 3% in construction cost, more than offset by savings in special programs and placements. The items listed below will add cost for the school systems that are currently not incorporating them in their designs.

Architectural materials and finishes selection and construction details

- higher STC building enclosure including insulating windows and doors;
- higher STC floor-ceiling assemblies;
- solid doors with quiet closers;
- higher quality doors including "sound doors" with gaskets and seals;
- more absorptive ceiling tiles;
- extra layer(s) of drywall or masonry unit insulation and heavier foundations;
- extra time and materials by contractor for tight sealing practices; and
- some additional initial engineering costs.

HVAC equipment selection and system design

- central, ducted mechanical systems;
- longer duct runs;
- quieter equipment performance specifications;
- reduced number of common ducts serving more than one room;
- larger duct cross-sections requiring higher floor to floor dimensions;
- more open grilles and diffusers;
- more vibration/isolation controls;
- sound dampers in duct work; and
- less ceiling mounted equipment and more equipment in properly constructed equipment rooms requiring larger building envelop, but potentially lowering operating costs.

In addition to initial costs, school systems must look at long-term maintenance and replacement costs. The life cycle cost approach includes these operations and maintenance cost impacts. Long term maintenance and replacement costs for durable building materials such as masonry and insulating windows may be lower than for lighter quality, more easily damaged, construction types that have a lower life expectancy and require more frequent replacement. Central HVAC systems are thought to be more sophisticated and expensive to maintain than room-by-room systems, but offer energy savings. The environmental and acoustic qualities they add are considered well worth the cost by many school systems. Maintaining some specialty items such as vinyl door seals will add minor costs.

NEW CONSTRUCTION GUIDELINES

The first and most cost effective step in achieving good noise isolation between learning spaces and other spaces in a school is accomplished in the facility planning stage. School facilities should be sited and designed to isolate inside learning spaces from outdoor transportation noise sources such as airports and major highways. Architectural designers must consciously locate noisy spaces and activities within the school to protect sensitive learning spaces. Designers must recognize the inherent tension between the lecture model of instruction with fixed locations for people and equipment and the models that emphasize active, student-lead collaboration with teams and equipment everywhere.

Planning

- Process/procedures/calculations. Coordinate actions of architect, general building contractor, school system facility design staff, equipment suppliers, and persons with professional experience in building noise control technology. The Standard provides substantial design guidance in Annexes B, C, and D to help minimize or eliminate the need for expertise in building noise control that may not otherwise be readily available to the project architect. Guidance is also provided in this document.

- Site selection. Do not select noisy sites; e.g., sites exceeding a Day-Night Average A-weighted sound level (LDN) of 60-65 dB for conventional construction or 65-75 dB for extra noise isolation construction. Never select sites with an LDN more than 75 dB. Avoid sites near major highways, airports, and noisy industrial plants.

- Spatial adjacencies within or near the building shell. Separate noisy, public, active zones from quiet study areas. Use storage rooms and other ancillary spaces to buffer noisy rooms. Locate playgrounds away from classrooms.

Architectural Design

- Design walls and partitions to meet STC ratings criteria.

- Specify ceiling tile and, if required, wall acoustic treatment to meet the reverberation control requirements of the Standard. Annex C of the Standard is especially useful in this regard.

- Limit or omit open space classrooms in the school.

- Specify sound insulating windows to block street noise or other environmental noises.

- For general classrooms with no fixed lecture position and ceiling less than about 3 m. (10 ft.), place most if not all sound absorbing material on ceiling. Over 3 m., an increasing amount will have to be on walls.

- For lecture type classrooms, it is best to ring upper wall and ceiling with sound absorbing material. In lecture halls, use sound reflecting material over the lectern, sound absorbing upholstered chairs, back wall sound absorbing or tilted orientation. In this case, consulting support by professionals is recommended.

- For classrooms with fixed or predominant teacher position, don't place sound absorbing material just above and in front of teacher's position.

- Corridors should generally have total surface area of sound absorbing material on the ceiling or walls not less than 50% of the floor area and up to 75% overall. 75% treatment area is recommended for corridors with high traffic or noisy lockers.

- For cafeterias and large CLS with ceiling height up to 3.7 m. (12 ft.), suspended ceiling with NRC of 0.70 or higher should be used for full ceiling area less lights and ventilation grilles. Test results published by manufacturers typically assume an air space of sixteen inches above suspended ceilings. Less height is acceptable for frequencies 500 Hz and higher. For heights at 12 ft. or above, see Annex C of the Standard for guidance or consult an expert and plan on including some treatment on walls.

- Carpeting can be helpful for muffling chair and foot sounds from students; however, it is not effective alone at providing sound absorption and is a poor sound absorber for low frequencies. MSDE does not recommend the general use of carpet in classrooms due to potential indoor air quality concerns unless a high level of maintenance is available.

- Stagger room entrances along corridors to reduce direct sound transmission through open doors.

- Use wall mounted indirect light fixtures or pendent mounted fixtures rather than ceiling transfer fixtures to maximize the ceiling area available for acoustic treatment.

- Avoid fluorescent lighting systems with ballasts that emit a constant hum.

- Cross-reference all noise control and isolation measures in design and procurement specification. Refer to Standard Practice for Installing Sound-Isolating Gypsum Board Partitions (ASTM E497) and Standard Practice for Use of Sealants in Acoustical Applications (ASTM C919).

Furnishings and Equipment

- Select chair and table legs with casters or slides compatible with the flooring.

- Select instructional equipment with quiet motors and fans.

- Locate instructional equipment as far as possible from students or place equipment in noise isolating enclosures.

- For computer labs, select low noise computers and add more sound absorbing treatments.

Mechanical System Design

- Provide a central HVAC system that locates noisy fans and compressors away from classrooms and delivers air at low velocity.

- Most currently manufactured non-ducted systems such as window-mounted room air conditioners and classroom unit ventilators should not be employed because the sound they produce is inherently unable to conform to the background noise level criteria in Table 1.

HVAC Air Distribution Systems

- All grilles and diffusers should be selected to have a catalog Noise Criteria (NC) rating of NC 18 or less.

- Airflow velocities in trunk ducts should not exceed 4.1m/s (800 ft/min). Branch ductwork sizes should match the air devices duct connection size. Duct silencers will be required inside the air-handling unit or in the main supply and return air ducts in most systems.

- All ductwork should be fabricated and installed to achieve a low static pressure loss. To achieve the rated performance of air diffusers, the plenum depth should be the equivalent of at least three to four diameters of the duct going to the diffuser.

- Avoid sharp edges and transitions in duct design. Air turbulence increases flow noise generated by duct fittings and dampers. Avoid expansion angles greater than 15 degrees that may produce rumble noise.

- Place air devices as far as possible from take-offs and elbows.

- Locate volume dampers no closer than 5 feet from an air device. The further a damper is installed from the outlet, the lower the resultant sound level.

- Minimize flow-generated noise from elbows or take-offs by locating them at least 4-5 duct diameters from each other.

- Use double thickness turning vanes in 90-degree elbows.

- Use low loss coefficient fittings, including 45-degree taps and laterals, conical branches, dovetails, etc.

- Provide 3 duct diameters of straight run at the inlet of Variable Air Volume (VAV) boxes.

- Provide a minimum of 4 feet downstream of VAV box connection before first air device runout.

- Extend fan outlet ducts 1.5 times the largest discharge duct dimension prior to elbows to minimize duct rumble. Elbows should turn the air in the same direction as the impeller rotation.

- Use an equalizer grid and/or plenum box with a side connection to provide uniform velocity distribution throughout the diffuser neck. A duct turn or misalignment in the duct connection between the air device and supply air duct can significantly increase the noise levels from HVAC systems.

- Divide the air stream such that the sound carried in each downstream duct is less than the upstream main.

- Ductwork serving adjacent learning spaces should include sound attenuators or sound absorbing duct lining (if required), or both to reduce cross talk through the duct.

HVAC Equipment Selection

- Specify/schedule maximum sound levels for equipment in critical locations.

- Select terminal control units (VAV boxes) for the lowest possible discharge and casing radiated Lw values in the 125 Hz octave band when tested per ARI Standard 880.

- Wherever possible, reduce noise by using variable speed motor drives to reduce motor speed.

- Consider draw-through units for systems with minimal return air ductwork (i.e., fan coil units and heat pumps) for the heat transfer coil to reduce radiated sound.

- Use appropriately sized plenum fans that produce lower discharge sound power levels than housed centrifugal fans.

- Use low revolutions per minute condenser fans for outdoor air-cooled equipment.

- Use compressor blankets to reduce compressor noise.

- Select fans at peak efficiencies.

- Select air moving equipment for the lowest possible low frequency octave band Lw values, as measured per ARI Standard 260.

- Replace fan sheaves to meet actual airflow and static pressure requirements in lieu of increasing restrictions through throttling devices such as dampers.

HVAC Noise Transmission

- Size HVAC piping based on a maximum of 4 feet per second velocity for pipe sizes 2 inches and smaller, and 10 feet per second for larger pipe sizes using a pressure drop limitation of 4 feet w.g. per 100 feet of pipe length to minimize flow noise.

- Locate equipment rooms away from critical areas. Locate buffer spaces such as corridors, storage rooms, toilet rooms, and so forth adjacent to mechanical equipment spaces.

- Locate equipment on slab on grade in equipment rooms wherever possible.
- Use masonry blocks, concrete heavy mass materials for equipment room walls and floors.
- Use solid structure, heavy mass sound barriers around outdoor equipment.
- Locate rooftop equipment over non-noise-sensitive areas. The roof deck/ceiling system should be constructed to adequately attenuate the sound radiated from the bottom of the unit. For curb-mounted units, consider placing 2 - 3 inches of lightweight concrete on the roof deck inside the curb.
- Do not locate modulating control and/or regulating valves over noise-sensitive areas.
- Do not attach dry wall enclosures directly to ducts to reduce duct rumble noise.
- Duct, conduit, and pipe wall/floor penetrations shall be sleeved and packed with Fiberglass and sealed on both sides.
- Consider using acoustical sandwich pads comprised of a cork center between two neoprene pads, which forces sound to change velocity in lieu of standard neoprene pads.
- Keep outdoor HVAC units away from windows.
- Prevent direct contact between ductwork and building surfaces or other equipment/systems.
- Locate heat pumps and fan coil units in mechanical closets in lieu of above ceilings.
- VAV boxes and fan-powered boxes should not be located over core learning spaces.

HVAC Vibration Isolation

- Provide all reciprocating and rotating equipment with vibration isolation to minimize structure-borne sound.
- Provide flexible connectors for piping ductwork and electrical conduits connected to rotating or reciprocating equipment.
- Provide vibration isolation for ducts and pipes for at least 50 feet from the vibration isolated equipment.
- All rotating equipment and equipment with static pressure control dampers should be 3.3 m. (10 ft.) or farther, if possible, from the classroom. HVAC fan equipment serving more than one classroom should be farther from the classrooms than equipment serving only one classroom.
- Centrifugal fans with airfoil shaped blades should be used in most cases. Fans with forward curved blades should be avoided.

Plumbing Noise Control

For the purpose of the Standard, plumbing system noise is not measured as background noise in "unoccupied space," but it is important to consider in the design.

- Run piping above corridor ceilings, not above learning spaces.
- Locate restrooms away from classrooms. (This may be difficult, especially in elementary schools.)
- Use cast iron waste water pipes, when possible. Wrap plastic piping with one or more layers of sound attenuating material. Wrap plastic waste pipe with sound absorbing material and box it with gypsum wallboard.
- Isolate all water piping from the building walls and structure by using manufactured vibration isolation fittings or neoprene pad wraps.
- Reduce the pressure of the supply water as much as possible and employ trapped air water hammer arrestors for water supply pipes serving flush or solenoid valve fixtures to reduce water hammer noise.
- Use water siphon jet fixtures instead of blowout fixtures.
- Inspect all plumbing installations for conformance to noise control features before sealing the walls.

Construction

- Insist that construction supervisors maintain good workmanship.
- Monitor construction. Check sealant at time of installation.
- Provide specific training for tradesmen, if necessary.
- Fill all joints wider than 6 mm (0.25 in.) with solid filler. Seal all openings.
- Check for compliance before acceptance.
- For single stud walls, electrical outlet boxes on opposing walls should never be in the same stud space.
- For dual-stud walls, the boxes should be separated by at least 0.6 m (24 inches).
- When it is necessary for a plumbing wall chase to be adjacent to a learning space, the wall should employ double stud construction (with a minimum 2.5 cm [1 inch] gap between the two rows of studs) with two layers of gypsum board on the classroom side and sound absorbing insulation batts in both stud cavities.

Post-Occupancy

- Be alert and monitor for degradation of acoustical materials, such as vinyl door seals or absorptive ceiling tiles.
- Monitor for degradation of mechanical system components.
- Consider investing in sound monitoring equipment and training to quickly respond to complaints.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MAJOR RENOVATION PROJECT GUIDELINES

The preceding new construction guidelines may be readily applied to renovation projects. Many renovations include work that will improve acoustics. There are opportunities to relocate spaces and buffer noise; enclose previously open space teaching areas; change the size, shape, and ceiling height of existing rooms; replace mechanical systems; install upgraded acoustic ceiling or wall panels; upgrade windows and doors; specify quieter plumbing systems; and seal openings in new partitions. In public assembly spaces and areas where other acoustic solutions have not worked, hearing assistance devices, such as FM amplification systems, may be installed. These actions, typically incorporated in major renovations, will improve acoustics, bringing spaces to, or close to, meeting the Standard at moderate additional cost.

EXISTING BUILDING ACOUSTIC RETROFIT GUIDELINES

The percentage of newly constructed or totally renovated schools in most school systems is very small. Facilities planners and school administrators will more often be asked to respond to the acoustic needs of individual students as defined in their IEPs or to complaints from teachers about particular settings. Parents of deaf and hard of hearing students are increasingly aware of the Standard. Special education coordinators expect the design criteria in the Standard to be cited frequently in IEPs.

It is fairly easy to identify acoustic problems. A simple test is to stand in a noisy part of the room, close your eyes, and listen to a short list of similar words read quietly. If you miss some of the words, the room probably needs remediation. A more detailed "do-it-yourself" diagnostic guide is provided in Sutherland and Lubman, 2004. For more quantifiable results, sound level meters are readily available to measure background noise. These require some training and experience to use effectively. The more accurate (better quality) equipment will cost approximately $500 to $1,000. School-based audiologists and speech/language pathologists may already have and use sound level meters that should be at least ANSI Type II or better. Some simple assessment factors are listed below.

Likely Reverberation Problems

- room has hard ceiling with no acoustical ceiling tiles;
- ceiling is more than 10% non-absorptive (light fixtures, HVAC grills, etc.);
- room has high ceilings over 11 feet; and
- ceiling tiles have been painted and lost acoustical absorbency.

Likely Background Noise Problems

- HVAC noise is clearly audible;
- teacher turns off mechanical equipment for important lessons;
- playground noise or automobile traffic noise is constant; and
- with HVAC system off, sounds from other rooms are clearly audible.

Remedies for acoustic problems are many and can be implemented in sequence from least to most costly. Some will help an individual student, some will help all students. Techniques include classroom management strategies, as well as architectural, engineering, and technological solutions. One United Kingdom study showed an average reverberation time of 0.7 seconds in 60 teaching spaces reduced to 0.4 seconds after acoustic treatment of the ceiling only. In general, remediating excessive reverberation is easily accomplished without significant expense. Overcoming intrusive outside, adjacent room, or HVAC noise will be more difficult and costly.

Classroom control and technology

- locate student with hearing loss closer to teacher in the classroom;
- arrange furniture to reduce distance between teacher and students;
- move student from noisy to quieter classroom;
- move student from relocatable classroom building to permanent school building with quieter HVAC systems;
- close windows and doors;
- reduce "self-noise" - wear quiet shoes, put tennis balls (or other padding) on chair legs, install carpet;
- replace noisy instructional equipment with quieter models;
- move noisy aquariums, etc., to other rooms;
- reduce class size; and
- provide a personal FM hearing-assist system. (Personal FM hearing assist systems deliver the teacher's voice directly to FM-linked earphones worn by the hard of hearing student and do not amplify this voice to others throughout the room).

Architectural design

- install new suspended acoustical tile ceiling, if room height permits;
- replace ceiling tile with a higher NRC-rated product;
- install acoustical wall panels high on walls at the sides and rear of the room;
- when high outdoor noise levels dictate the need:
  - add storm windows
  - replace existing windows with thermal (and sound) insulating units
  - install specially fabricated sound-reducing windows
- add good quality door seals and gaskets;
- replace doors with tight fitting solid core doors with quiet closers;
- consult with an architect about improving wall and roof construction;
- install blanket insulation above the ceiling to reduce sound transmission over the top of floor-to-ceiling partitions or bring partition to underside of slab, if feasible; and
- the addition of draperies or curtains and carpet has only a minor impact on acoustics.

Mechanical system noise control

- make sure systems work properly and receive regular maintenance;
- add a custom built sound enclosure around noisy unit;
- add sound-lined ductwork to lessen air distribution noise;
- replace unit with quieter system;

- increase opening area of grilles and diffusers; and
- rebalance system to reduce air volume delivered to classroom;
- relocate ductwork and diffusers away from key teaching locations;
- add separate duct runs to reduce HVAC noise; and
- add duct length to reduce HVAC noise.

SOUND FIELD AMPLIFICATION SYSTEMS

Sound field amplification systems are small public address systems that consist of a teacher-worn transmitter/microphone and speaker(s) strategically placed in the classroom. Speakers are often wall-mounted at a height just above the student's head. The purpose of this assistive technology is to improve the signal to noise ratio in the classroom by amplifying the teacher's voice to a level 5 to 10 dB above the classroom noise level.

The Standard does not provide recommendations for electronic amplification for persons with hearing impairments. Maryland State Department of Education recognizes a place for sound field amplification systems in retrofitting existing buildings where partial acoustic modifications have been unsuccessful. MSDE does not support widespread use of these systems in new construction. The first and best approach is to design new schools to meet the Standard. Additional information on sound field systems is included in Appendix A.

INDOOR AIR QUALITY (IAQ)

Carpet has a reputation for contributing to poor IAQ. From an acoustics point of view, carpet is primarily useful in reducing the amount of "self-noise" in a school, particularly minimizing the sound of chair legs and shoes on the classroom floor. The IAQ concerns with the use of carpet in schools relate to the use of adhesives during installation, need for routine cleaning and maintenance, and ability to meet appropriate replacement schedules. Good practice suggests that schools limit the use of carpet to areas that are not subject to water and food spills and heavy traffic. When carpet is used, it requires intensive maintenance including daily vacuuming with proper equipment, and shampooing and/or hot water extraction several times each year.

Both IAQ and acoustic standards promote the use of centralized HVAC systems. IAQ advocates caution against sound linings in ducts, which may be indicated as a retrofit for noisy HVAC distribution. Some lining materials can create an IAQ problem because internal duct lining may become wet and contribute to the growth of mold, but industry now produces moisture-resistant products. Limited use of sound control duct linings is acceptable when necessary. The use of interior perforated sheet metal liners allows internally lined ducts to be easily cleaned. In addition, the use of dedicated ventilation air/dehumidification units, which reheat the air above coil dew point temperatures, reduce the opportunity for internal duct linings to become wet.

PORTABLE CLASSROOM BUILDINGS

There are over 2,900 classrooms in portable buildings (also called "relocatables") in use at public schools in Maryland. The State of Maryland has adopted a statewide regulatory program for industrialized construction that includes portable classroom buildings. The Maryland Department of Housing and Community Development (MDHCD), Codes Administration adopts and enforces construction standards for industrialized buildings. Local jurisdictions regulate the installation and all on-site work, as well as fire control measures, land use, and zoning matters. Building manufacturers submit applications, drawings, specifications, and quality assurance manuals to Maryland Approved Testing Facilities for approval and certification of industrialized buildings. The MDHCD maintains a list of Maryland Approved Industrialized/Modular Building Manufacturers and Models.

Because these buildings use lightweight construction materials and individual classroom HVAC units, they typically do not meet the Standard or energy conservation and sustainability criteria. Students known to be at risk from poor acoustics (students learning English as a second language, with learning disabilities, with hearing losses, and very young children generally) should not be assigned to portable classrooms. In addition, the greater the distance between adjacent relocatables, the less noise will intrude through the walls.

RECOMMENDED SOURCES OF ADDITIONAL INFORMATION

The Maryland State Department of Education strongly recommend all school systems and designers obtain a copy of the Standard.

For Acoustical Guidelines for Schools:
American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Acoustical Society of America, Melville, New York, June 26, 2002, 50 p. Report No: ANSI S12.60-2002, $35.00. NOW AVAILABLE ONLINE AT NO COST.

To Order: Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114E
Melville, NY 11747-3177

Tel: 631-390-0215
Fax: 631-390-0217
https://asastore.aip.org/

For Basic Acoustics and Principles of Architectural Design:
Egan, M. David, *Architectural Acoustics*, McGraw-Hill, Inc., New York, 1988.

For Extensive Bibliographies and Links on School Facilities:
National Clearinghouse on Educational Facilities, www.edfacilities.org.

For Official Publications, Guidelines, and Extensive Background on All Accessibility Issues:
U.S. Access Board, www.access-board.gov.

For Architects:
*Standard Practice for Installing Sound-Isolating Gypsum Board Partition*s (ASTM E497).

Standard Practice for Use of Sealants in Acoustical Applications (ASTM C919).

For Mechanical Engineers
Chapter 46 - Sound and Vibration Control, 1999 ASHRAE *Applications Handbook* .

Chapter 7 - Sound and Vibration, *2001 ASHRAE Fundamentals Handbook*

Standard for Sound Ratings of Non-Ducted Indoor Air Conditioning Equipment, ARI 350-2000.

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APPENDIX

SOUND FIELD AMPLIFICATION SYSTEMS

Over the past 25 years, extensive research has demonstrated that classroom sound field amplification systems are an effective way to produce significant changes in students' listening behavior and academic achievement. Since the start of the Mainstream Amplification Resource Room (MARRS) Project in 1978 (which was validated by the U.S. Department of Education), sound field amplification systems have been used in classrooms throughout the country. The MARRS Project research revealed extensive benefits from the use of classroom sound field systems. Key research findings between 1978 and 1993 include:

- Greater academic achievement at a faster rate for all learners at one-tenth the cost of instruction in unamplified resource rooms (Sarff, 1981; Ray, 1992; Ray, Sarff & Grassford, 1984);
- Significant improvement in word and sentence recognition for typical students with normal hearing (Crandell & Bess, 1986; Jones, Berg, & Viehweg, 1989; Crandell, 1993), for students with developmental disabilities (Flexer, Millin, & Brown, 1990), for students who were non-native English learners (Crandell, 1994), and for students with minimal degrees of hearing loss (Jones, Berg. & Viehweg, 1989; Neuss, Blair & Viehweg, 1991);
- Improved academic performance of typical learners (Sarff, 1981; Flexer, 1989; Osbourn, VonderEmbse, & Graves, 1989; Ray, Sarff & Glassford, 1992; Ray, 1992; Zabel & Tabor, 1993; Flexer, Richards, & Buie, 1993; Rosenberg, Blake-Rahter, Allen. & Redmond, 1994) and learners with minimal hearing loss or histories of middle-ear problems (Schermer, 1991; Flexer, Richards & Buie, 1993); and
- Improved on-task or listening behaviors for preschool, primary, and secondary school students (Benafield, 1990; Gilman & Danzer, 1989; Allen & Patton, 1989).

From 1993 to 1995, the Improving Classroom Acoustics (ICA) Project corroborated and expanded on MARRS Project research. The ICA Project, funded by the Florida Department of Education, Division of Public Schools, involved 2,054 students in kindergarten, first, and second grade general education classrooms in 33 elementary schools in Florida. With evaluations completed by 1,221 students, 55 general education classroom teachers, 630 parents, and 27 school administrators, results strongly demonstrated that an enhanced acoustical environment using sound field classroom amplification benefited students and teachers alike. Results confirmed that students' listening and learning behaviors and skills improved and that teachers experienced less voice strain, fatigue, and emotional strain.

The American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools does not provide recommendations for electronic amplification for persons with hearing impairments. The Maryland State Department of Education recognizes a place for sound field amplification systems in retrofitting existing buildings where partial acoustic modifications have been unsuccessful. MSDE does not support widespread use of these systems in new construction. The first and best approach is to design new schools to meet the Standard.

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Bluffdale, Utah 84065
1-800-383-9362
1-801-254-3802 FAX
www.audioenhancement.com

Lifeline Amplification Systems
41 Means Drive, Suite A
Platteville, Wisconsin 53818
1-800-236-4327
1-608-348-7918 FAX
www.lifelineamp.com

Light Speed Technologies
11509 SW Harman Road
Tualatin Oregon 97062
1-800-732-8999
1-503-684-3197 FAX
www.lightspeedtek.com

Listen Technologies, Corp.
8535 South 700 West, Suite A
Sandy, Utah 84070
1-800-330-0891
1-801-233-8995
www.listentech.com

Phonic Ear, Inc
3880 Cypress Drive
Petaluma, California 94954-7600
1-800-227-0735
1-707-769-9624
www.phonicear.com

Sennheiser Electronic Corp.
One Enterprise Drive
Old Lyme, Connecticut 06371
1-860-434-9190
1-860-434-1759 FAX
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Teachlogic, Inc.
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1-949-951-6822 FAX
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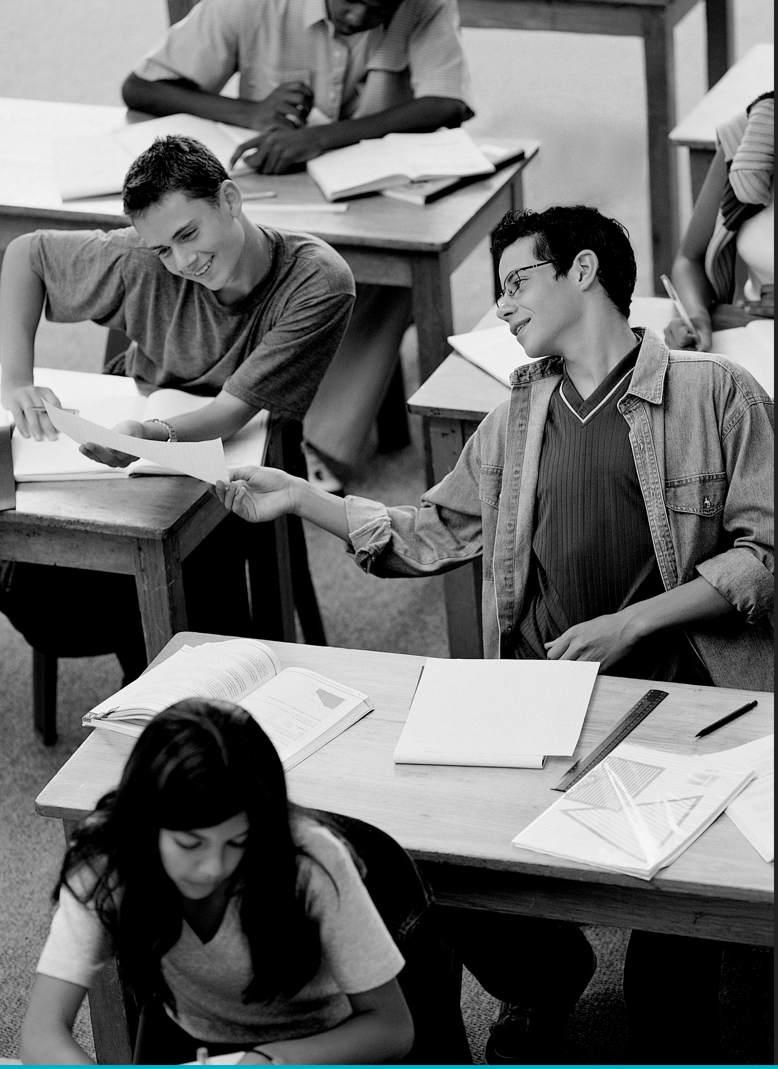

"Children are not only smaller and noisier than adults, they are immature and inefficient listeners who are developing their speech perception abilities until their teen years"

P. Nelson

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Achievement Matters Most

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